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Field methods for determining point source pollution impacts in rivers: A case study of the Grindsted stream

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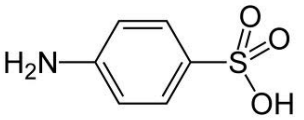
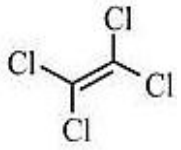
DTU Miljø

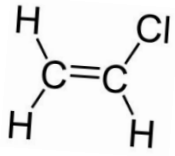
Institut for Vand og Miljøteknologi

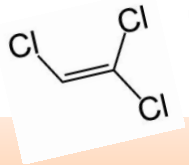
Motivation



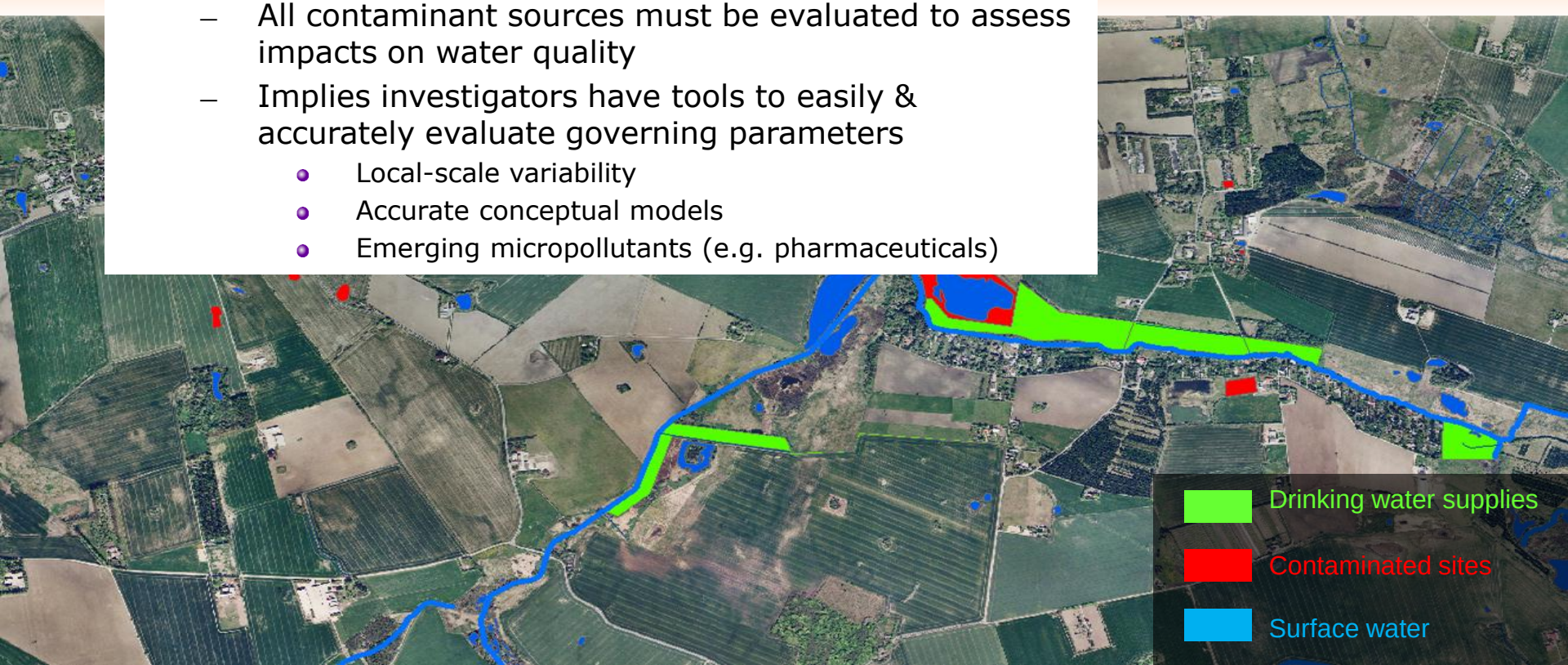
- **Streams: where pressures come together**
  - Significant contamination on catchment-scale
  - To improve risk assessments (source-path-receptor): understanding GW-SW interactions is crucial







- **EU WFD: good chemical status**
  - All contaminant sources must be evaluated to assess impacts on water quality
  - Implies investigators have tools to easily & accurately evaluate governing parameters
    - Local-scale variability
    - Accurate conceptual models
    - Emerging micropollutants (e.g. pharmaceuticals)

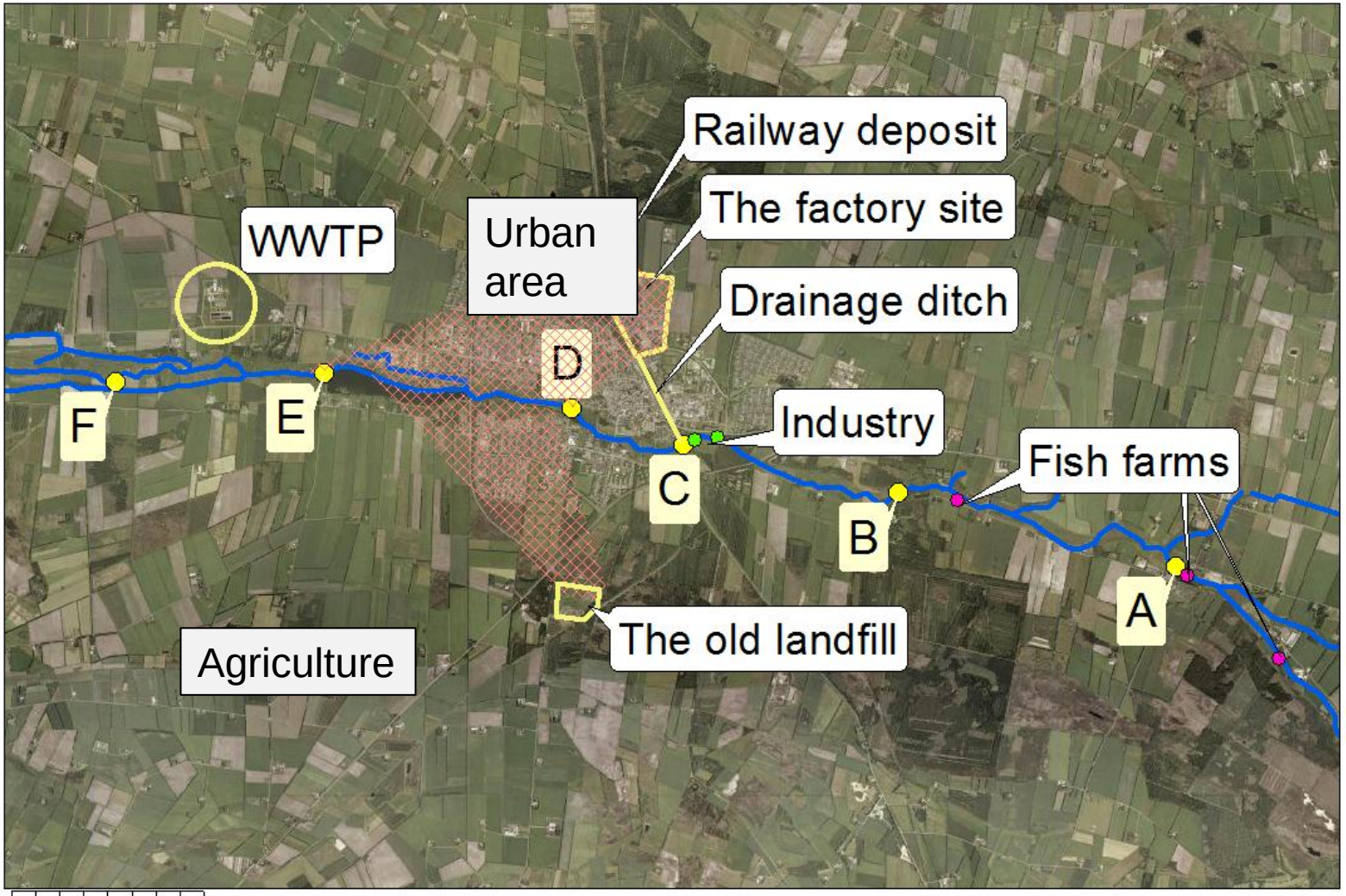


Project overview

- **Part of: ”Risk assessment of surface water affected by point sources of contaminated groundwater”**
  - Collaboration project: Orbicon, DTU Environment, Region Syddanmark (contract holder, co-funding)
  - Danish EPA (Technology development funding – TUP)
  - Technical Report for Danish EPA; incl. an appendix: “Feltundersøgelser ved Grindsted Å: Metoder og påvirkning fra punktkilder

- **Develop a scientific (faglig) basis for conducting risk assessments for contaminated sites impacting streams**
  - Groundwater flow: important part of total water supply to stream
  - Well-studied site:
    - 2 of DK’s “megasites”, remediation costs >10 MDKK
    - Where 43 of 129 (Miljøstyrelsen, 2012) are potential threat to surface waters: both sites located within 2 km of stream
      - Grindsted factory (Grindstedværket)
      - Grindsted landfill (Grindsted gamle losseplads)

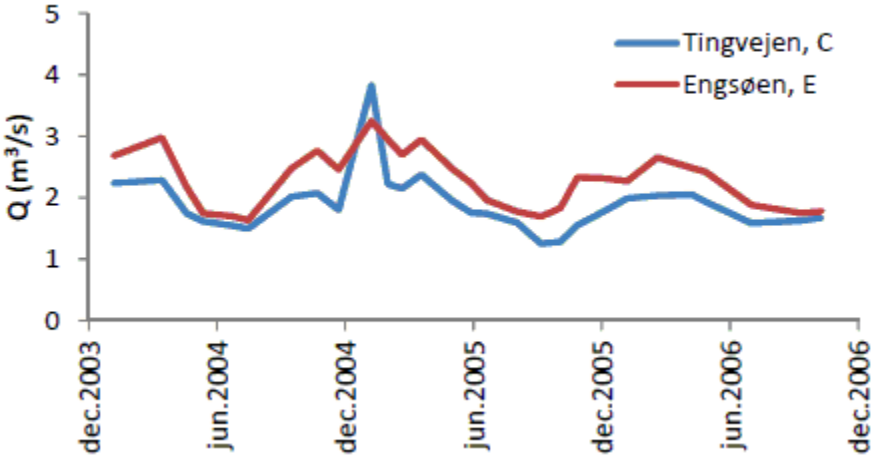
Grindsted town: contaminant sources

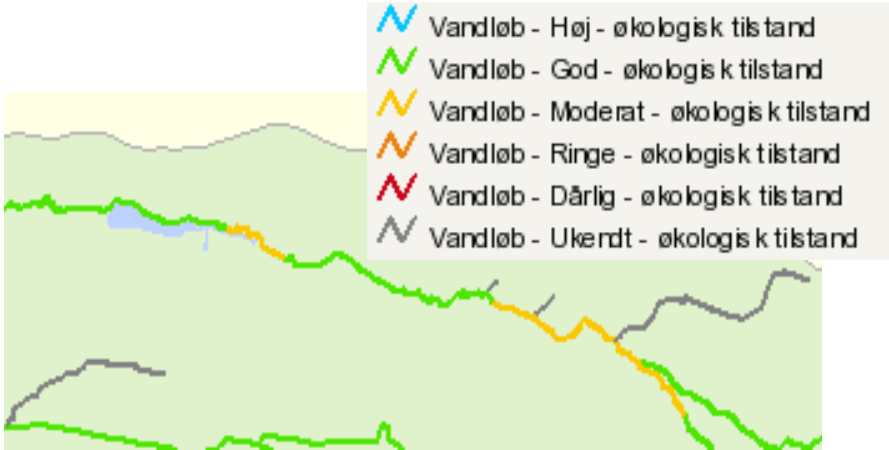


Petersen (2012). DTU MSc Thesis.

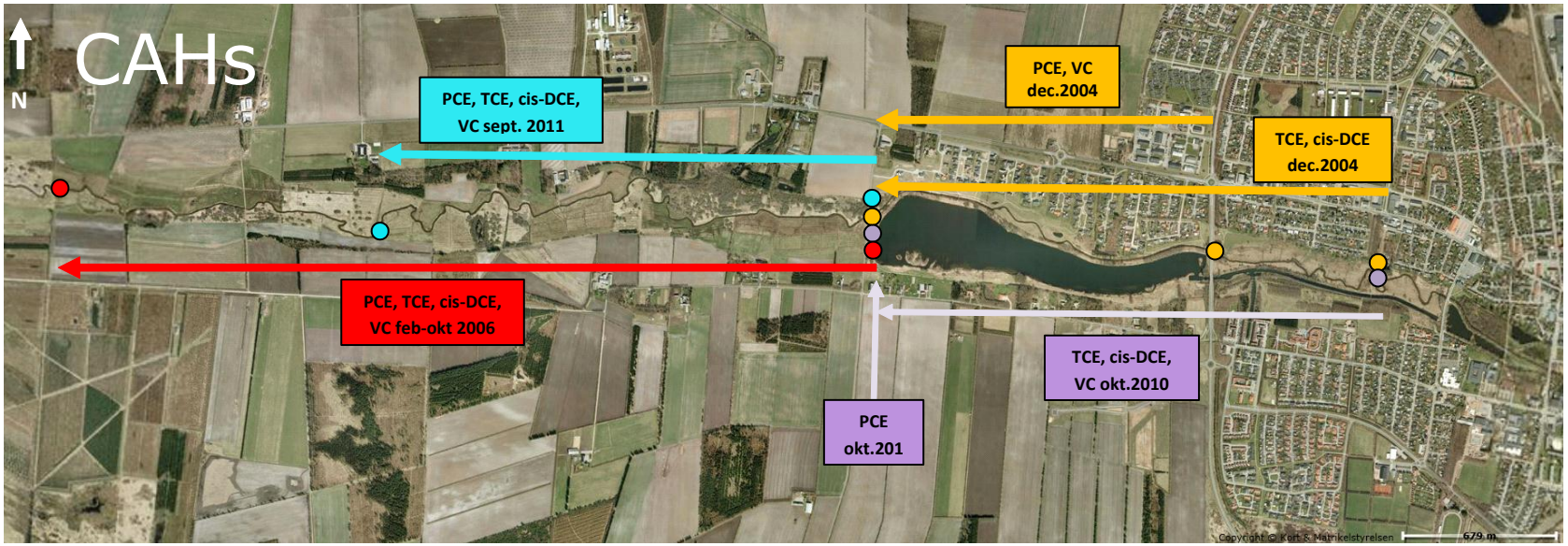
Grindsted stream

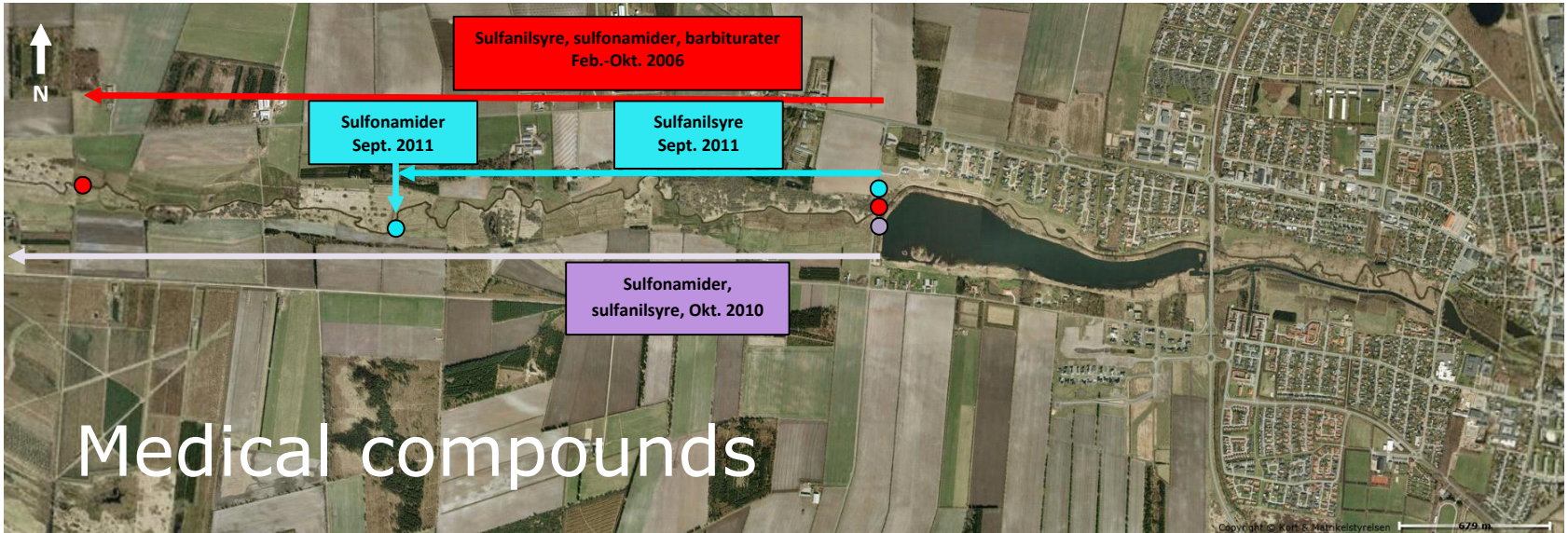
- Median minimum flow: 1.8 m^3/s
  - High flow for Danish stream
- Thought to be a gaining stream
  - Flow downstream 0.4 m^3/s higher
- Land-use dominated by agriculture
  - Multiple stressors; complex site
- Ecological status (DSFI): good to moderate





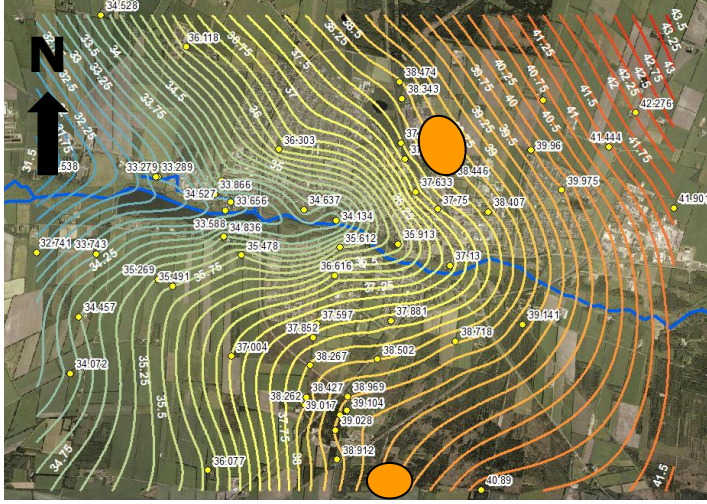
Chlorinated solvents & medical compounds





Conceptual model

- Geology: sand underlain by clay
- Groundwater flow
  - Blue lines: equipotentials for hydraulic head
  - Black arrows: indicate groundwater flow direction



Petersen (2012). DTU MSc Thesis, based on Orbicon (2012).

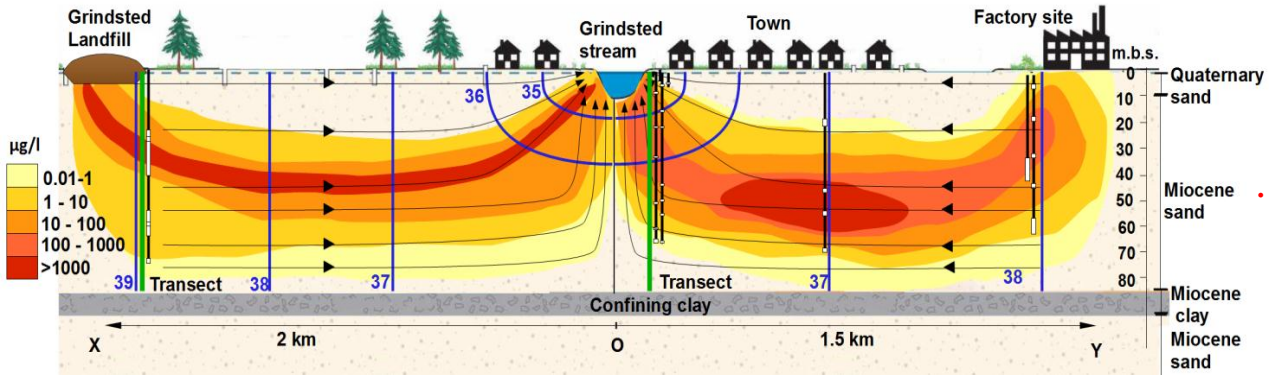
(south) Grindsted landfill

Grindsted factory (north)

FOOTPRINT

- Li [µg/L]
- Medical compounds

(Ejlskov, 2005)
(Bjerg & Kjeldsen, 2010)
(Region Syddanmark, 2012)



Petersen (2012). DTU MSc Thesis.

FOOTPRINT

- Br [mg/L]
- Medical compounds
- Chlorinated solvents

(Ejlskov, 2006)
(Region Syddanmark, 2006)

Study objectives

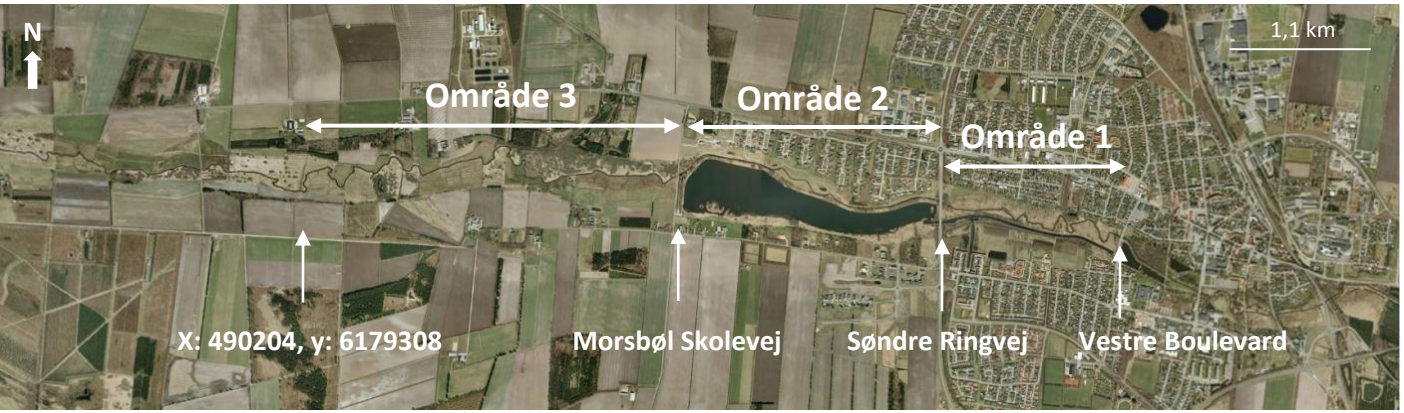
1. **Test applicability of different methods** for mapping groundwater pollution entering streams
   - Identify potential "contact" zones (over 5 km)
   - Correlate to surface water contamination

2. **Identify & separate entry points** for both plumes to Grindsted stream
   - Methodology
   - Unique compositional footprint

3. **Give practical recommendations** for conducting risk assessments of other sites

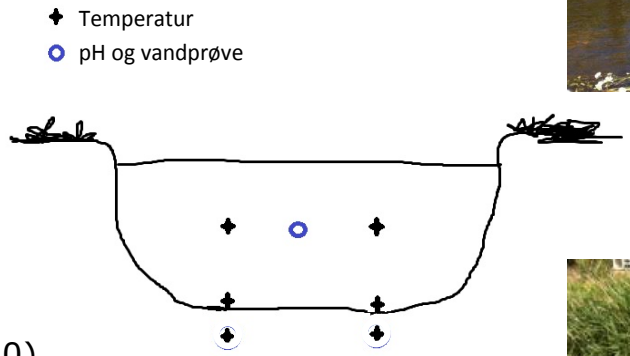
4. **Perform risk assessment** of stream's chemical status
   - Assess environmental quality standard (EQS) thresholds

Grindsted stream



Methods applied

- **Temperature:**
  - Every 50m
  - Both sides of stream
  - 3 depths
    - Center of stream
    - Streambed
    - 20 cm below streambed (T20)
  - Piezometers placed & sampled where T20< 10˚C



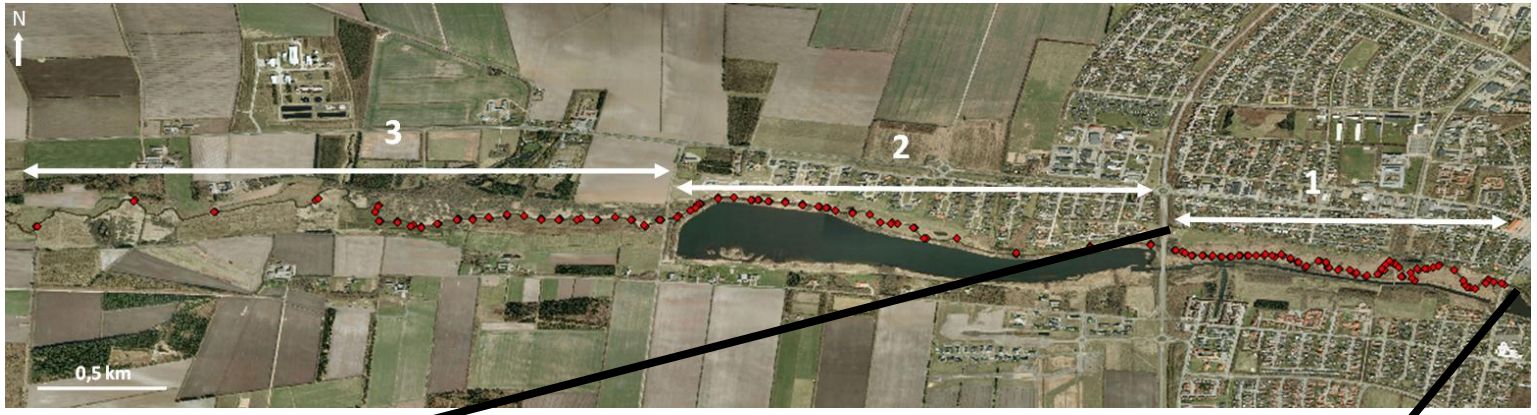
- **Surface water samples**
  - Every 50-100 m
  - Center of stream

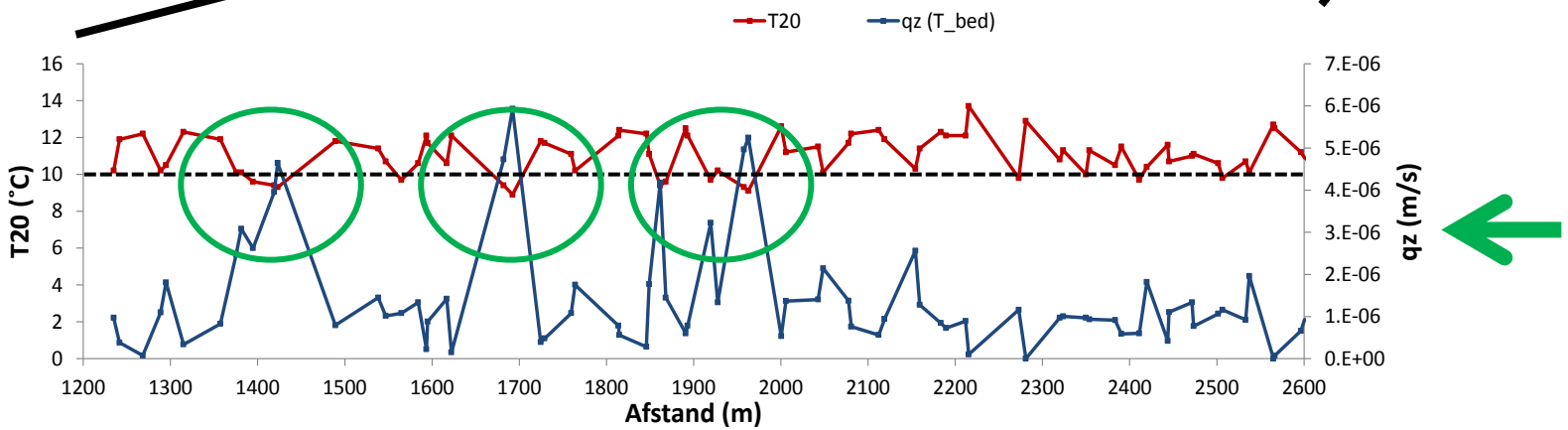
- **Hyporheic zone water samples**
  - All piezometers, 40 cm below streambed

- **Groundwater samples**
  - Along stream bank transects

Identification of GW inflow zones

Measurement locations: 2 to 191



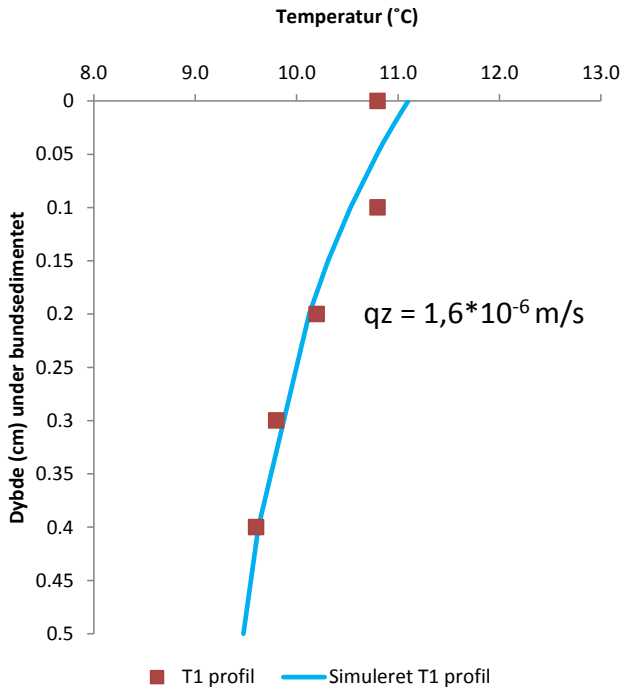


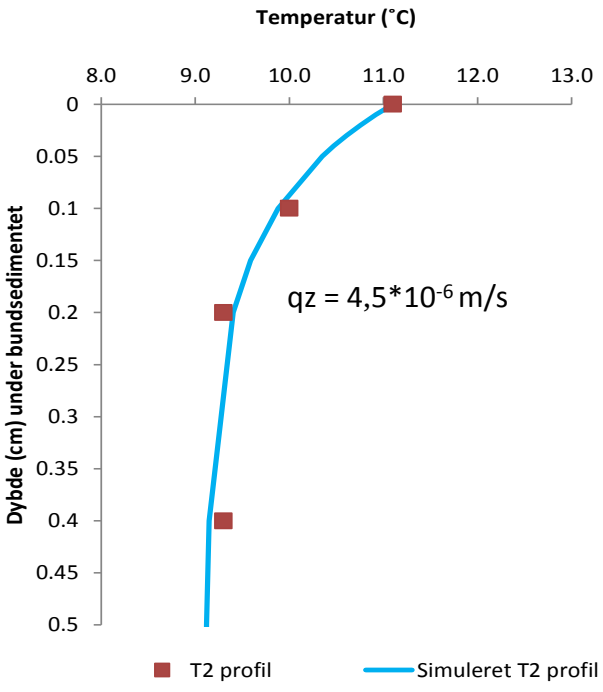
$$\frac{K_{fs}}{\rho c}\nabla^2 T(z) - \frac{\rho_f}{\rho c}\nabla\cdot(T(z)q_z) = \frac{\partial T(z)}{\partial t} \qquad q_z = -\frac{K_{fs}}{\rho_f c_f z}\cdot \ln\left(\frac{T_{20}-T_L}{T_0-T_L}\right)$$

Schmidt et al. (2007)

Robust temperature measurements at 20 cm

- **Steady-state temperature profile**
- **Estimation of GW flux**



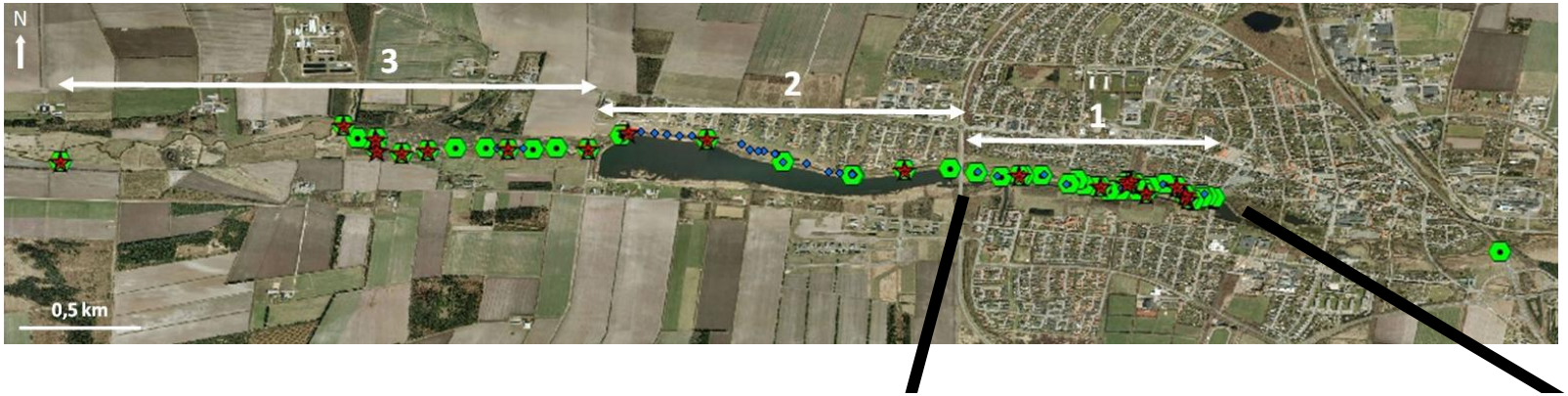


$$T(z) = T_0 + (T_{GW} - T_0)\frac{exp\left[N_{pe}\left(\frac{z}{L}\right)\right] - 1}{\exp(N_{pe}) - 1} \qquad N_{pe} = \frac{q_z \rho_f c_f L}{K_{fs}}$$

Bredehoeft & Papadopolus (1965)

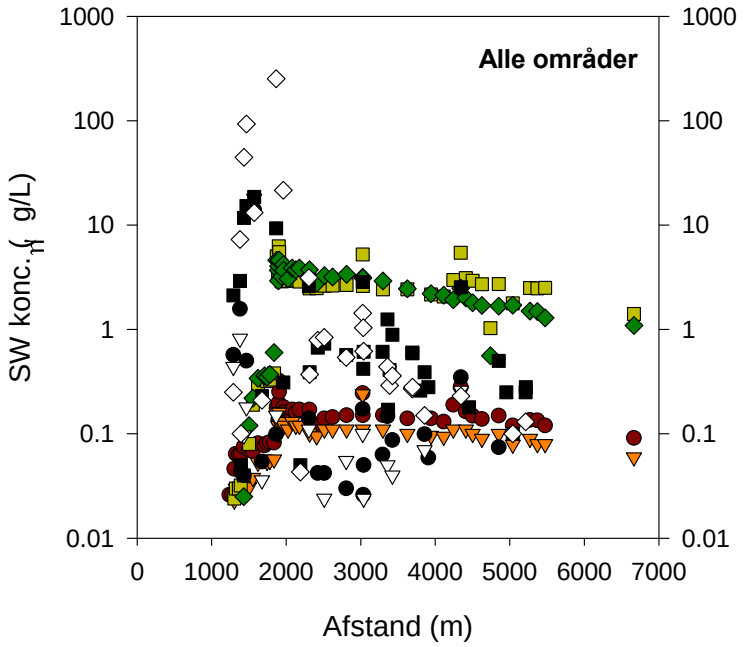
Stream water quality

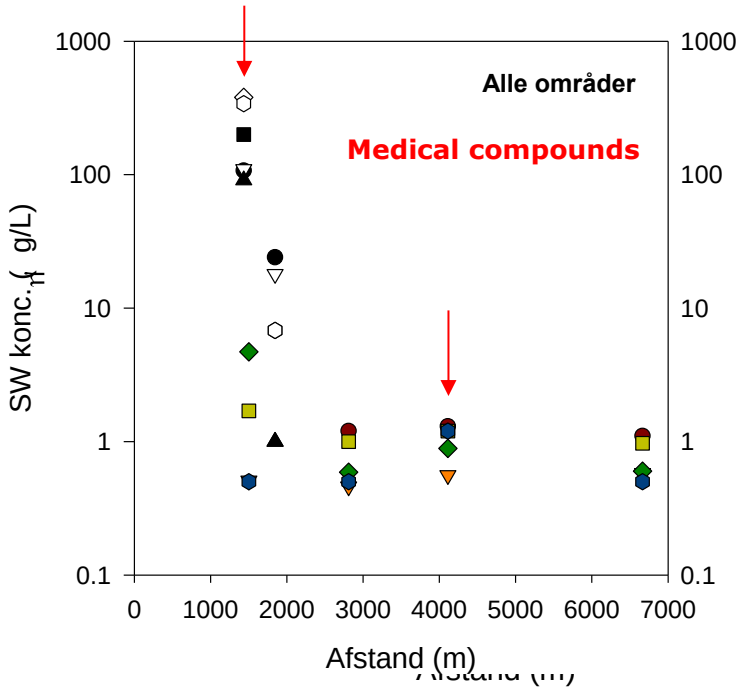
Measurement locations: 1 to 57



CAHs

PCE_SW
TCE_SW
cis_DCE_SW
VC_SW
PCE_GW
TCE_GW
cis_DCE_GW
VC_GW

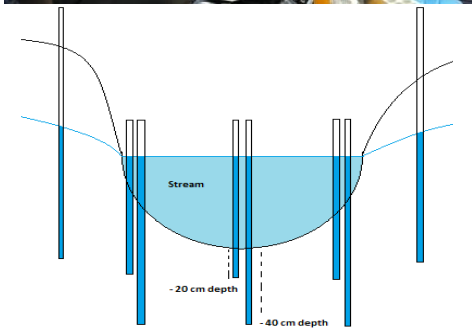


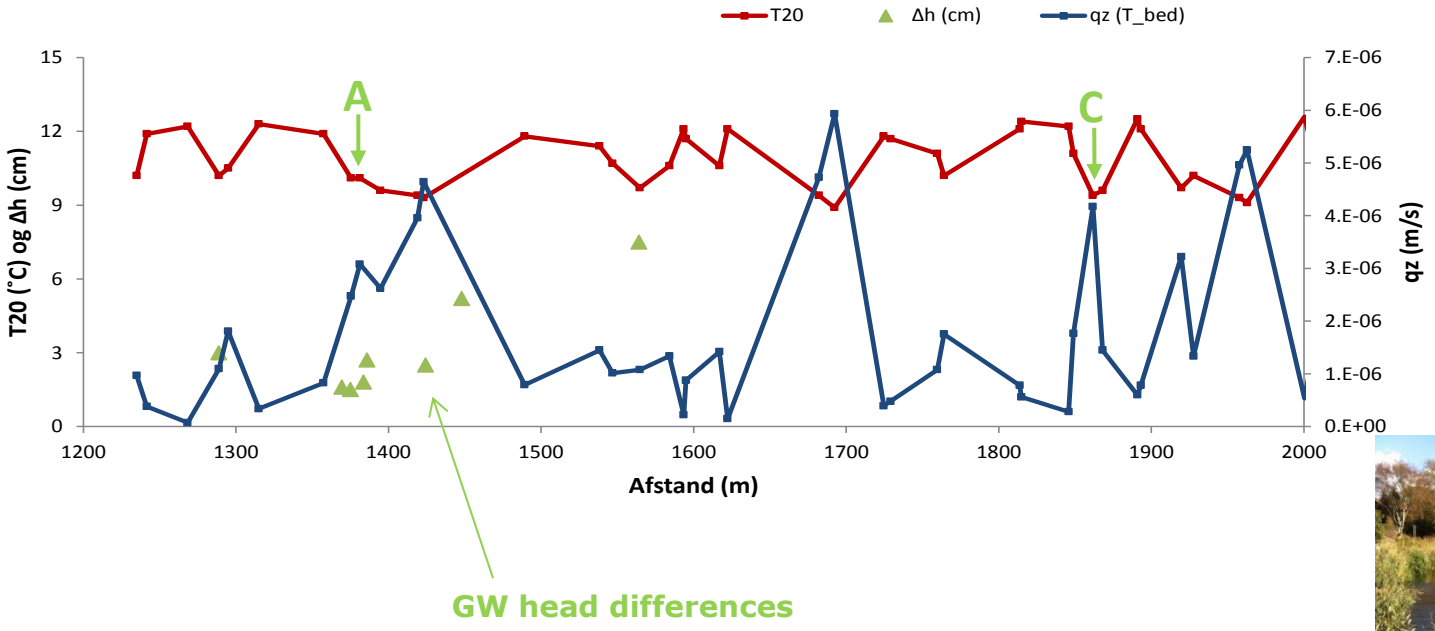


VC_GW

Transect investigations

- **Chemical, temperature and head data:**
  - Peaks for chlorinated solvents
  - Peaks for chloride/bromide in groundwater evident
    - Noticed simultaneous depletion of nitrate (& some sulphate) in groundwater
  - Temperature peaks (A & C)
  - Head data

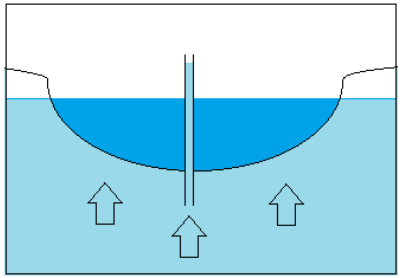


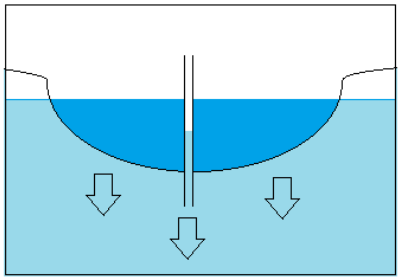


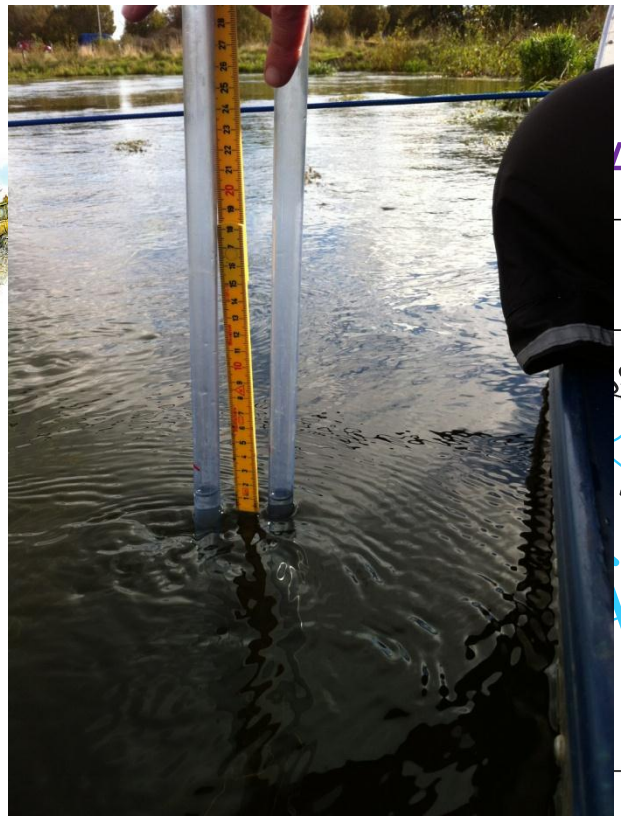
GW head differences

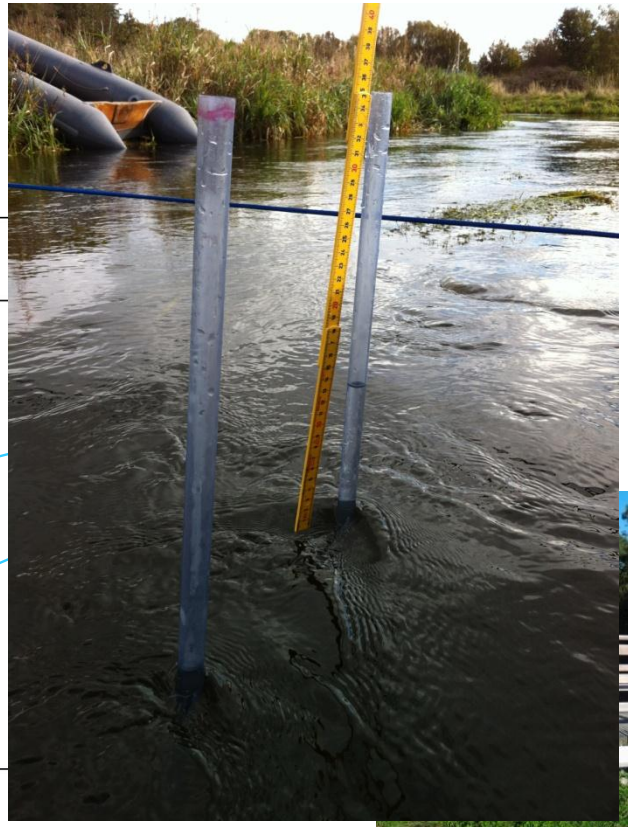
Vertical hydraulic gradients

- **Concept of measurement: Δh**





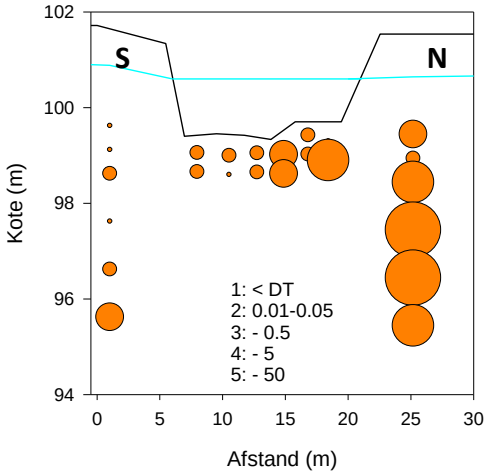




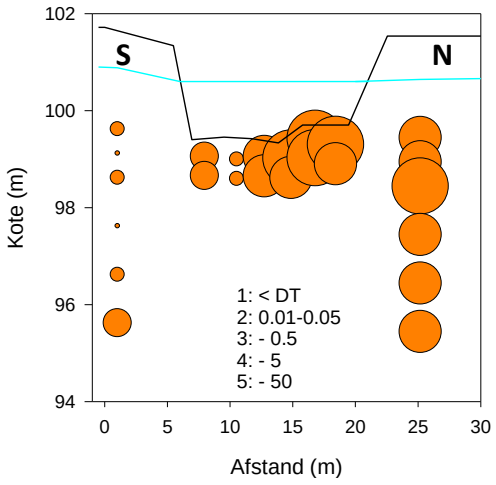
Locating the Grindsted factory plume

- Transect A: chlorinated solvents + Br

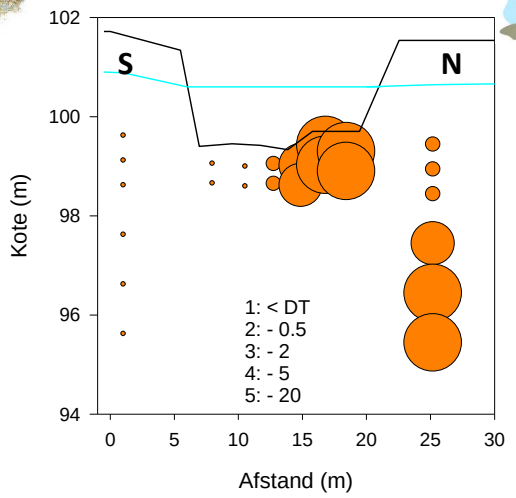
PCE



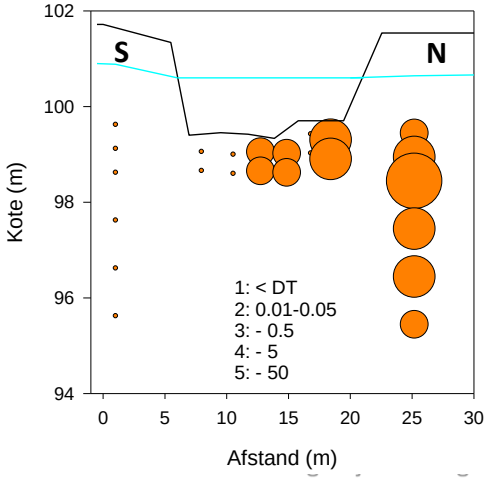
cis-DCE



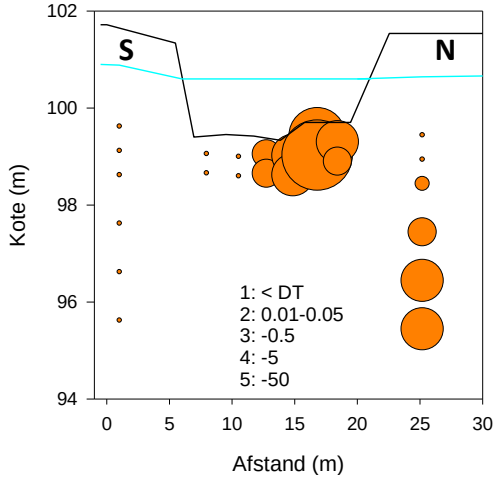
Bromid (mg/L)



TCE



VC



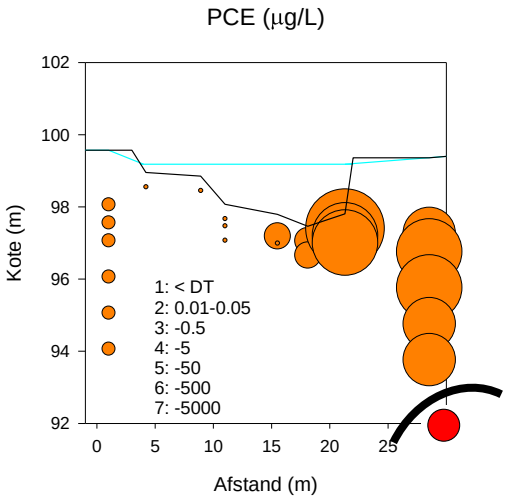
Eks. **- 0,5** i PCE betyder intervallet

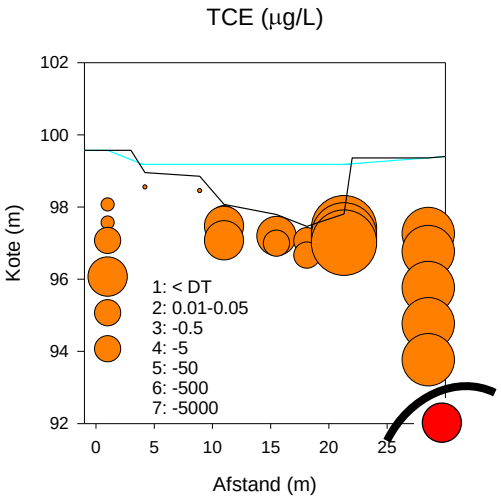
fra 0,05 til 0,5

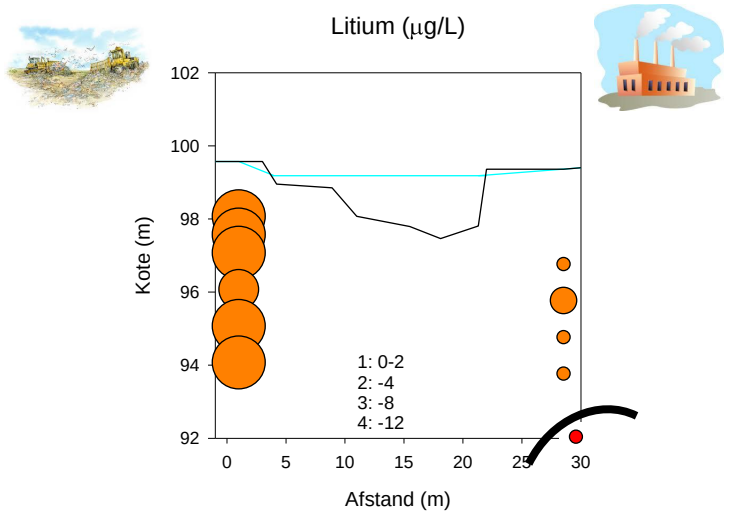
cis-DCE

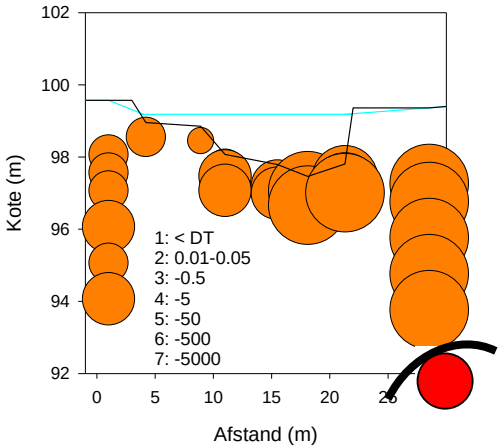
Locating the Grindsted landfill plume

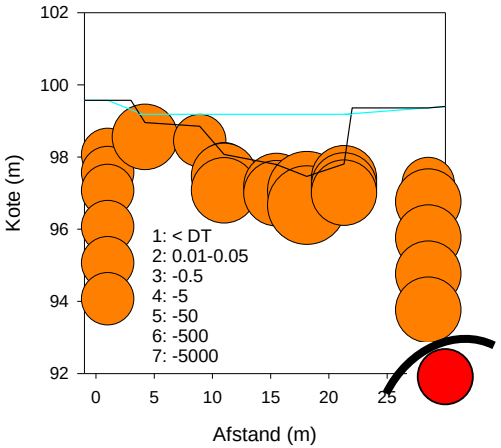
- Transect C: chlorinated solvents + Li







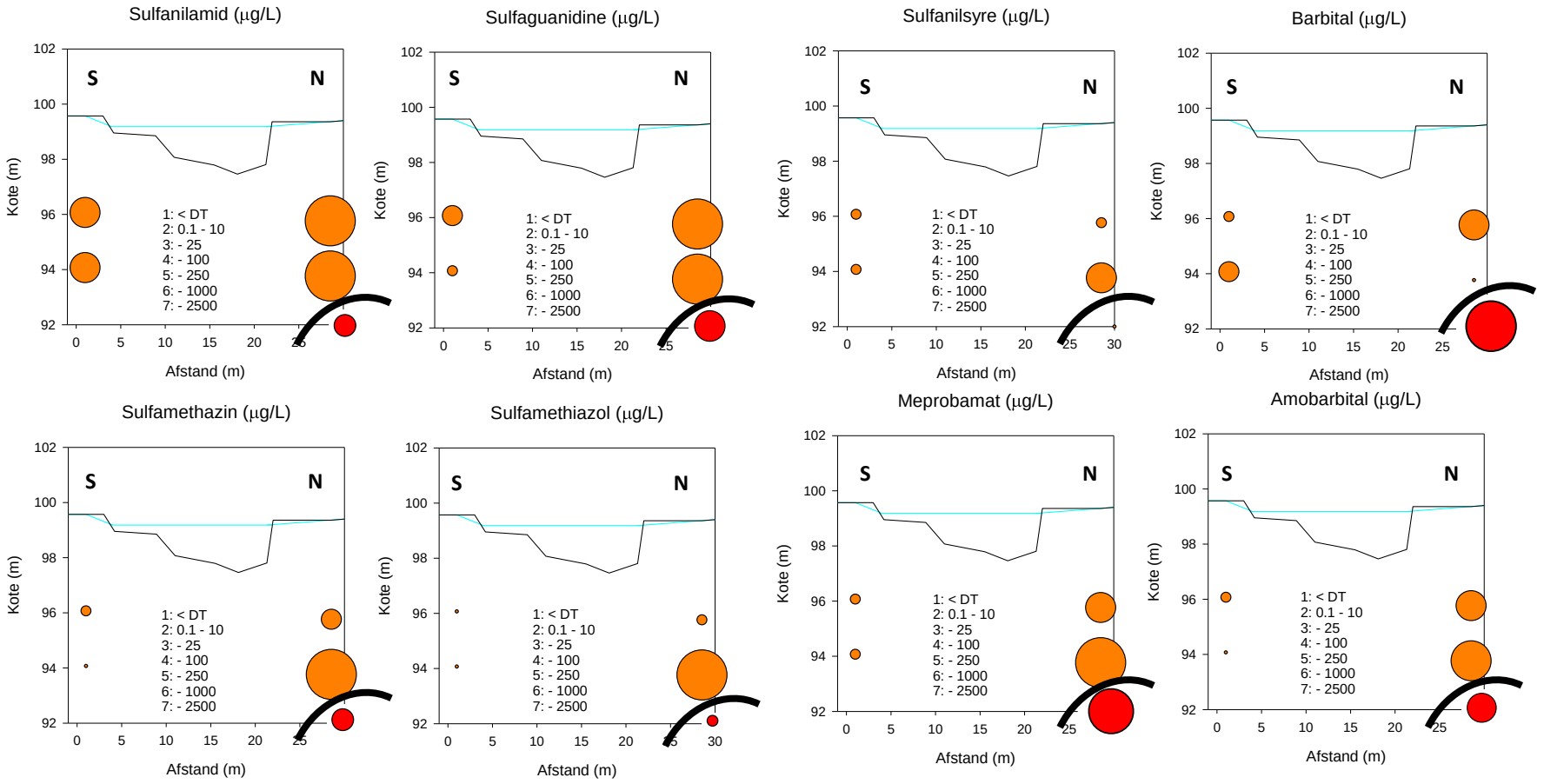




Eks. **- 0,5** i PCE betyder intervallet

fra 0,05 til 0,5

Medical compounds: Transect C

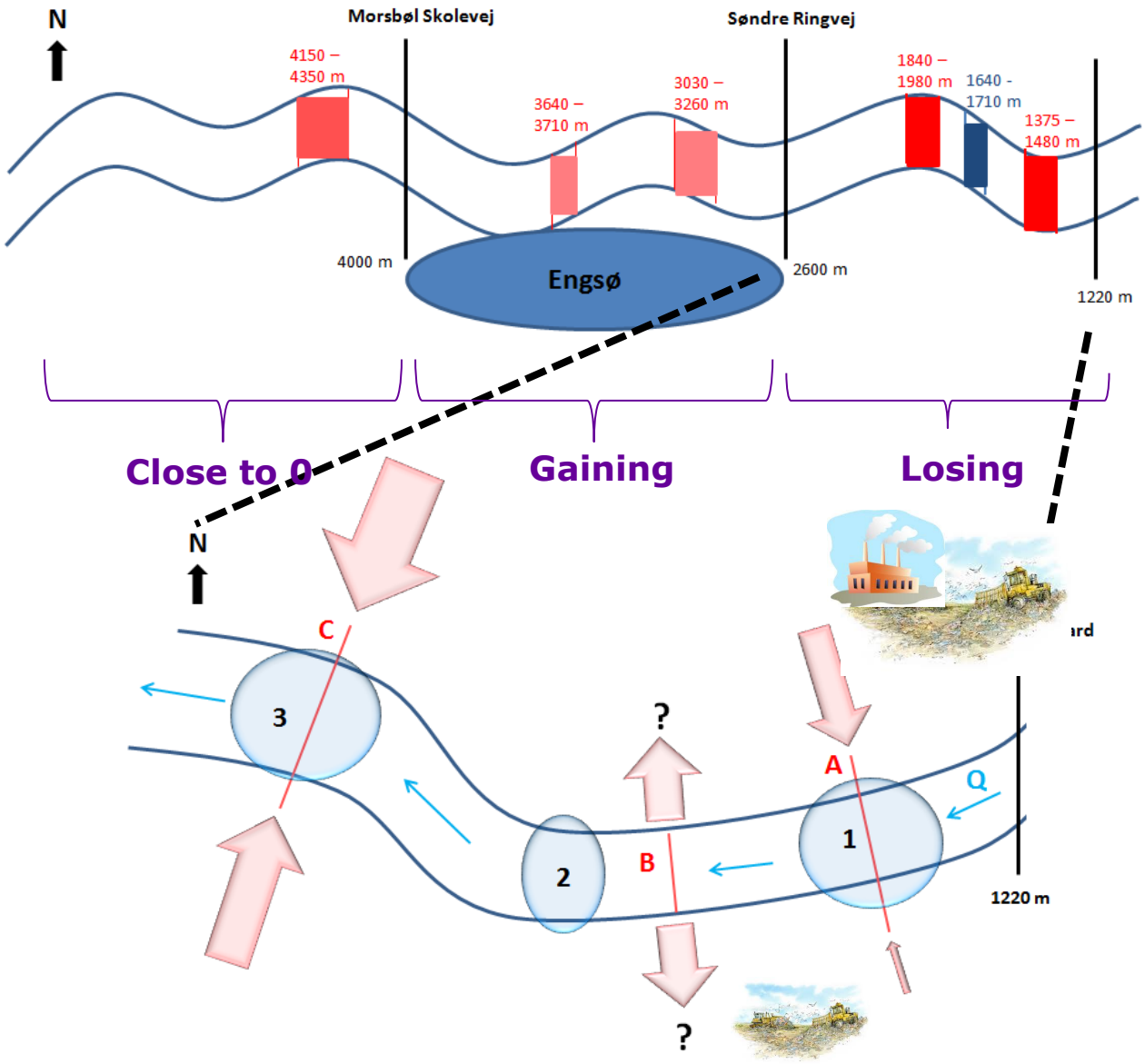


Eks. - **0,5** i PCE betyder intervallet

fra 0,05 til 0,5

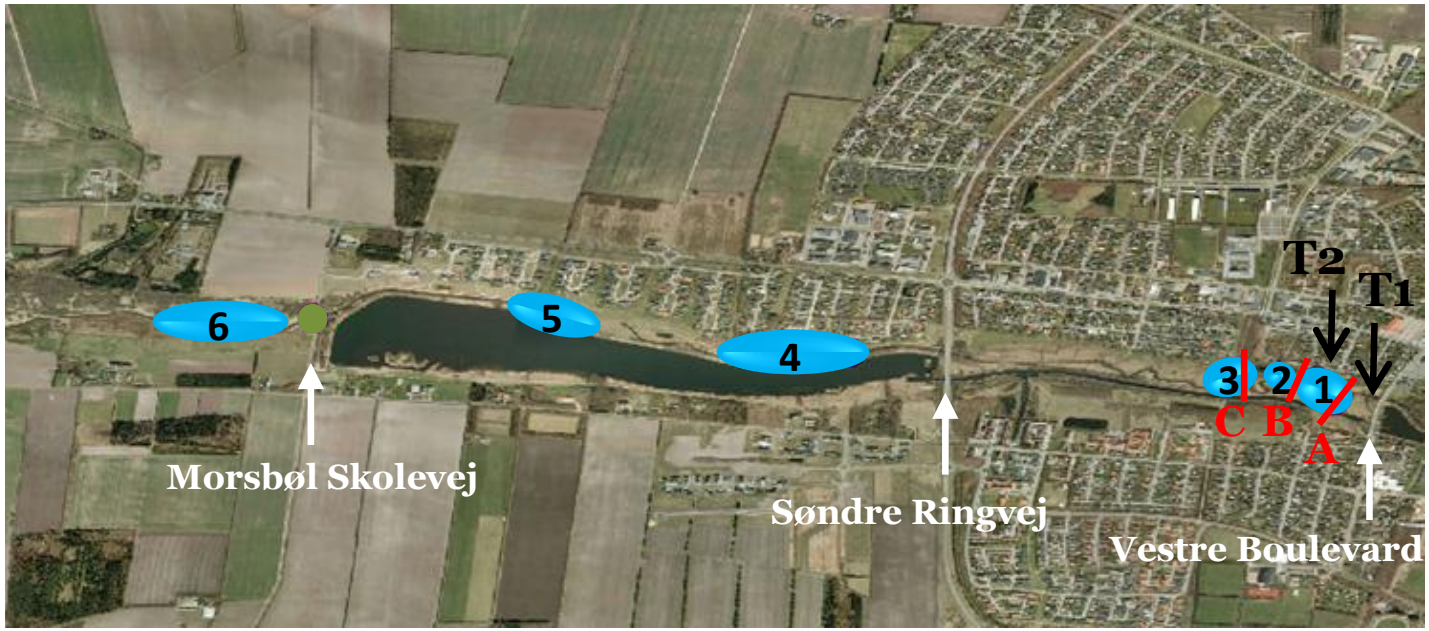
Final conceptual models

- **6 contact zones identified**
  - Regional investigation could not localize
- **2 highly contaminated contact zones**
  - Transect A & C: Grindsted factory plume
  - Landfill plume ??



Conclusions (1)

1. **Successfully detected 6 significant local-scale ”contact” zones along 5 km stream stretch**
   - Not visible at the regional scale
   - Temperature measurements very useful for local-scale delineation



Conclusions (2)

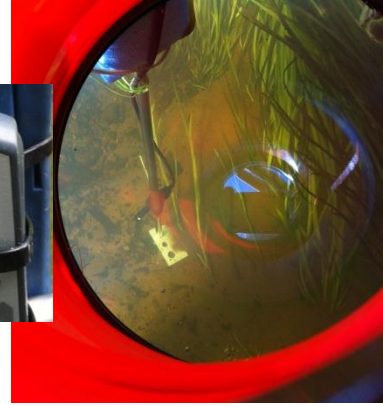
2a. Localized Grindsted factory plume (Transect A & C) through unique compositional footprint

- Further investigations necessary to finalize location of Grindsted landfill plume
- Recommend 2D cross-sectional characterization (on south side of Grindsted stream in Area 1) to identify direction and width of the landfill groundwater plume

2b. Correlated 2 highly contaminated (groundwater) contact zones to concentrations in stream water

- Highest CAH & ion concentrations detected in piezometers (hyporheic zone)

Conclusions (3)



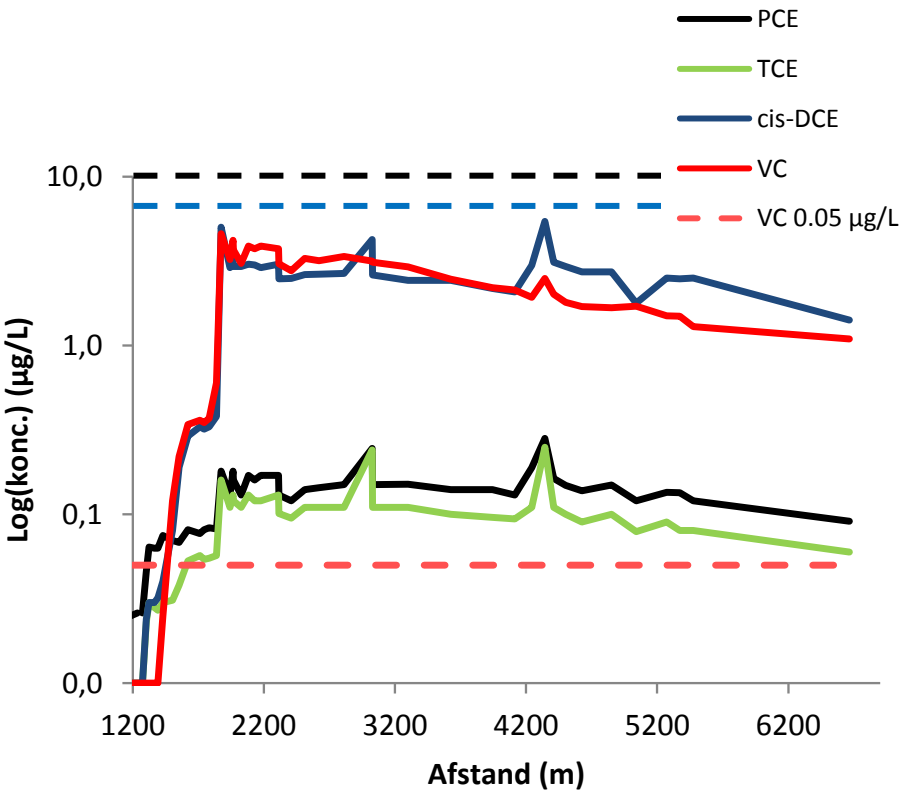
3. Practical recommendations

- Temperature measurements: quick & effective for detecting local contact zones
  - 50-100 m intervals
- Must be combined with chemical concentrations in surface water along stream
  - 50-100 m intervals
- Piezometer samples: are time-consuming, but essential to locate contaminanted GW influx zones to the stream (both laterally and transversally)

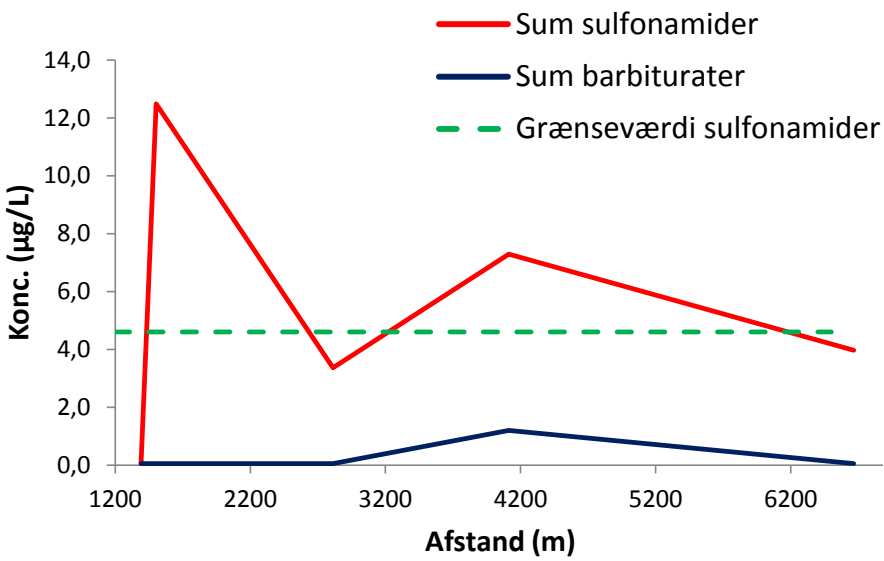
Conclusions (4)

4. Risk assessment

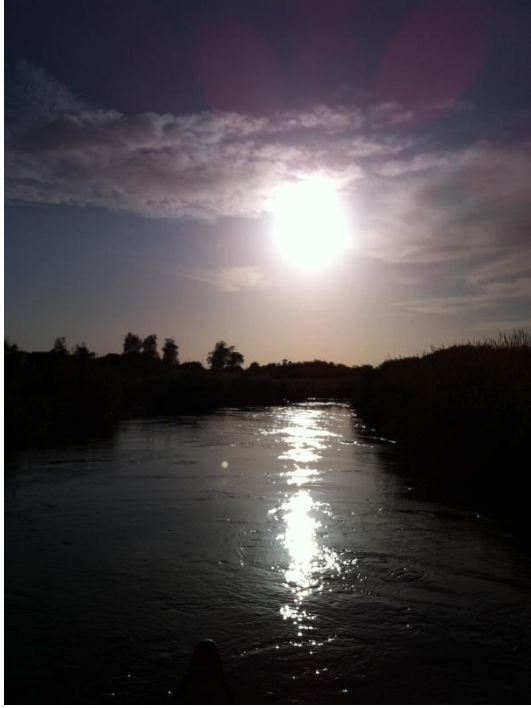
- Chlorinated solvents:
  Vinyl chloride >EQS (0.05 µg/L) in all areas once VC detected in stream



- Medical compounds
  ∑ sulfonamide concentrations > EQS (4.6 µg/L) twice along stream stretch



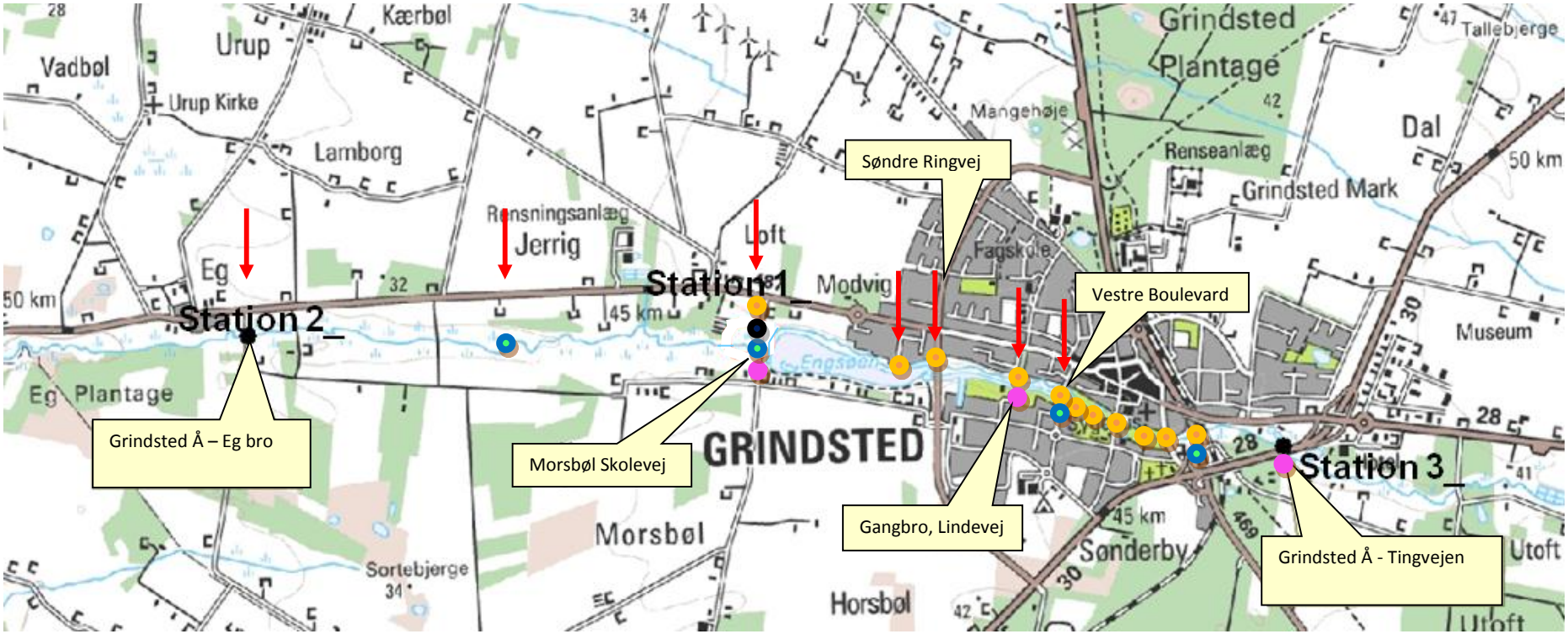
Acknowledgments



- **Orbicon**
- **Region Syddanmark**
- **Danish EPA**
- **Special thanks to:**
  - Bent Skov
  - Jens Schaarup
  - Sabrina Nedell
  - Anders Skovgård
  - Mikael E. Olsson
  - Morten Andreasen

Surface water: 2004-2011

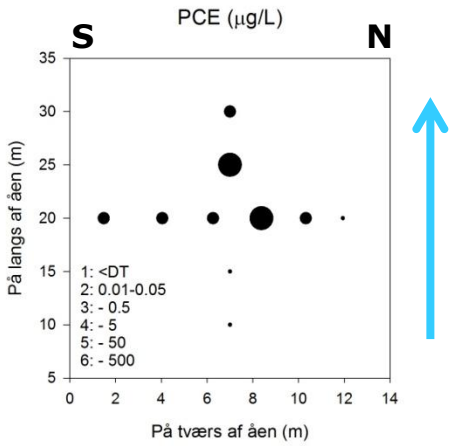
⟶ Indicates stations where CAHs detected

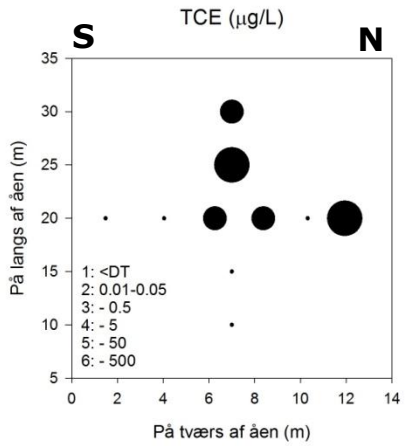


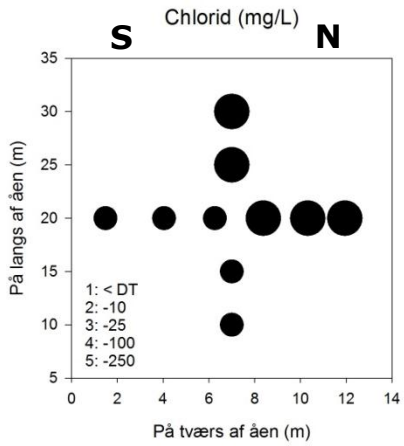
Temperature “spear”

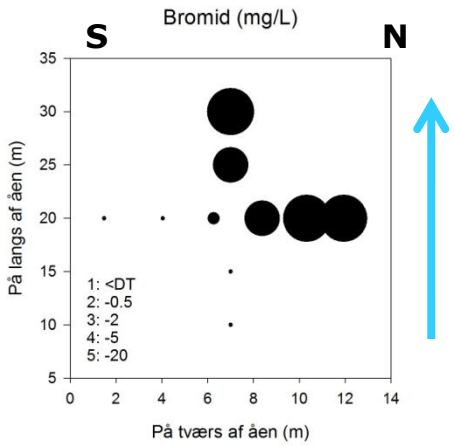
Hyporheic zone transect

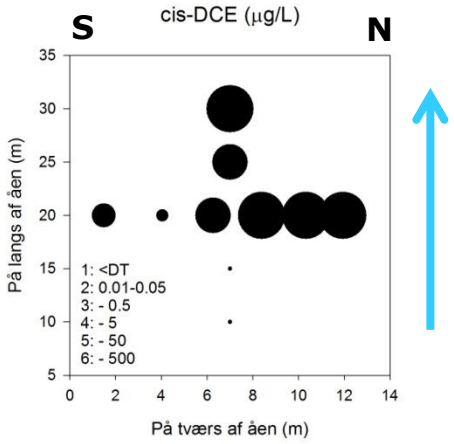
- Up- & downstream of Transect A, with flow

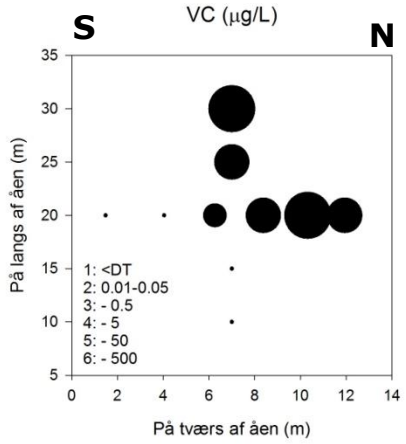


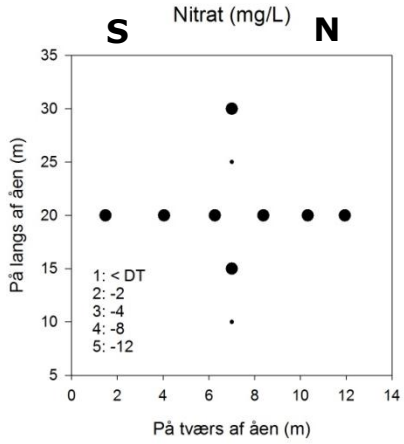


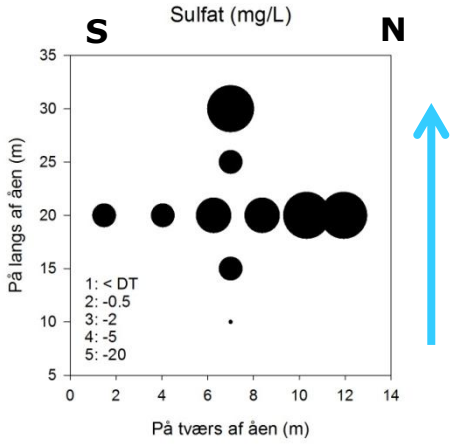






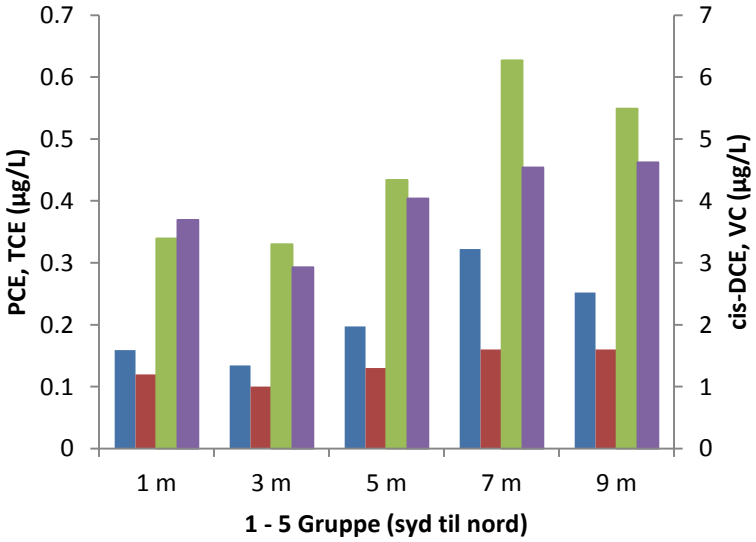


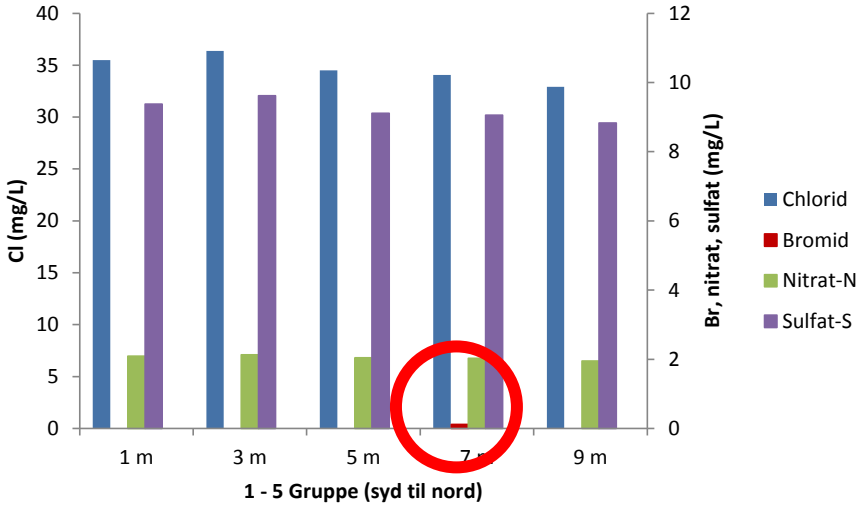




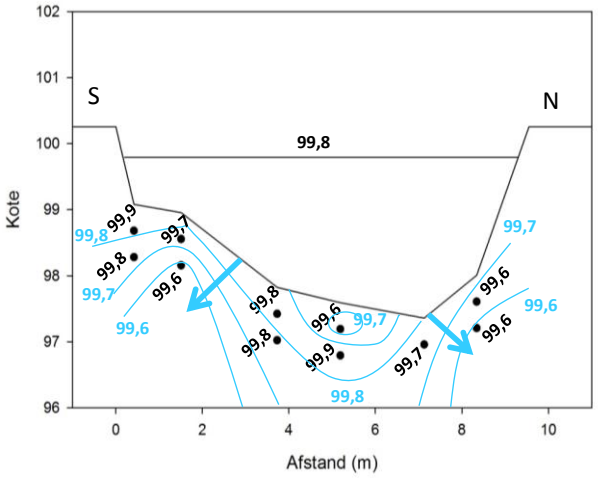
Surface water transect

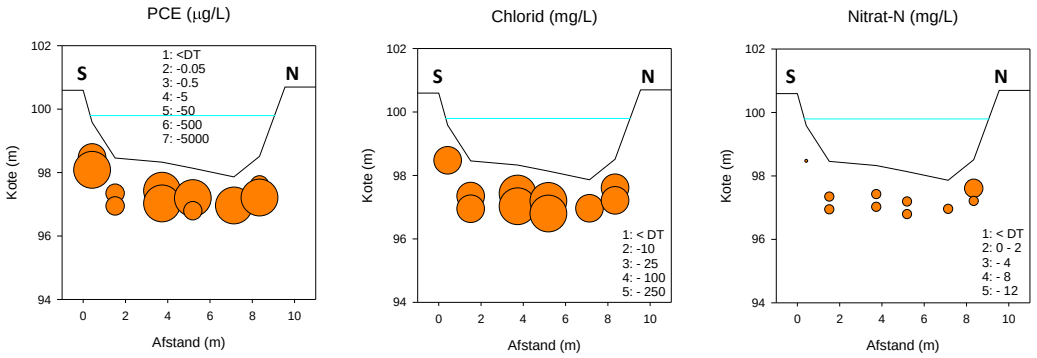
- 25 m downstream of Transect C, perpendicular to stream flow

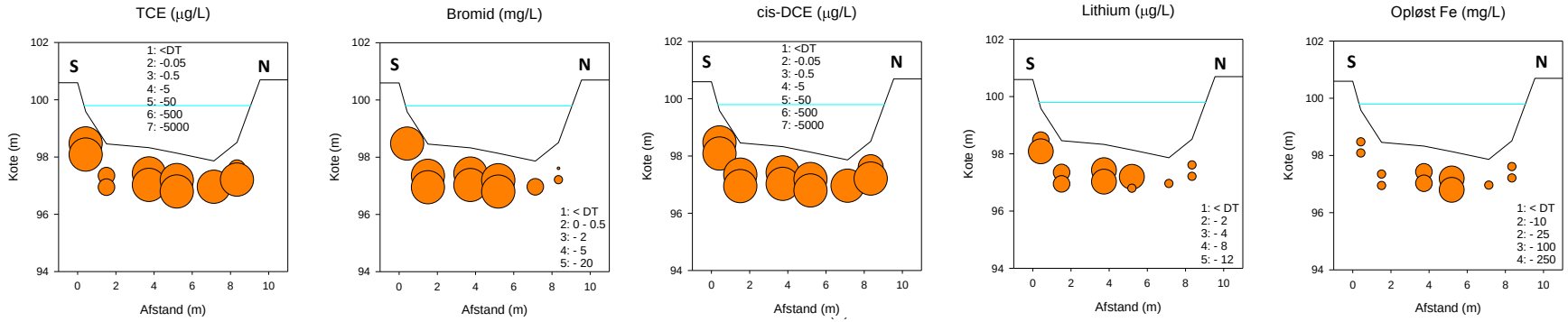




Results: Transect B







Eks. **- 0,5** i PCE betyder intervallet

fra 0,05 til 0,5